Reactive Compensation Capability Of Fixed Capacitor Thyristor Controlled Reactor For Load Power Factor Improvement: A Review

Harpreet Singh, Durga Sharma

Abstract: Reactive power compensation capability of a fixed capacitor thyristor controlled reactor type static VAr compensator is being investigated in this paper. The TCR has the power transfer controlling capability only in the lagging power factor range. The range of TCR can be extended by connecting a fixed capacitor in shunt with the TCR. The compensated reactive power can be selectively controlled by appropriately changing the firing angle of the TCR circuit in lagging as well as the leading power factor range. The application of fuzzy logic for the controlling of the FC-TCR system to improve the load power factor is also being discussed.

Keywords: fixed capacitor thyristor control reactor, fuzzy logic control reactive power compensation.

I. Introduction

Reactive power requirement of the electrical system has been increased due to the increase in use of the electrical machines and all other type of industrial loads used in the industry. On increase of the reactive power requirement at the load centre there occurs a decrease in load power factor. This can be achieved by the reactive power compensation provided by the fixed capacitors (FCs), static VAr compensator (SVCs) and/or synchronous motors (SMs). Conventional methods that were generally used for the reactive power compensation are the fixed and switching capacitors. They were having the problem of slow response to the changes. On the advent of power electronic switches like thyristor, IGBT, GTOs. Fast switching is possible and hence the dynamic response of the compensator can be improved. This paper proposes a fixed capacitor thyristor controlled reactor type of static VAr compensator which is being controlled by fuzzy logic controller. The controlling signal of the thyristor is being controlled by the fuzzy logic controller. Fuzzy controller is the attempt to apply human logic in an actual circuitry. The logic is being decided as per the experience of the logic. By using this method it is shown that the reactive power compensation can be done to a large range.

II. FIXED CAPACITOR THYRISTOR CONTROLLED REACTOR (FC-TCR)

Basically, the TCR only provides continuously controllable reactive power in the lagging power-factor range. To extend the dynamic controllable range to the leading power-factor domain, a fixed-capacitor bank is shunt-connected with the TCR. The TCR MVA is rated larger than the fixed capacitor to compensate (cancel) the capacitive MVA and provide net inductive-reactive power should a lagging power-factor operation be desired.

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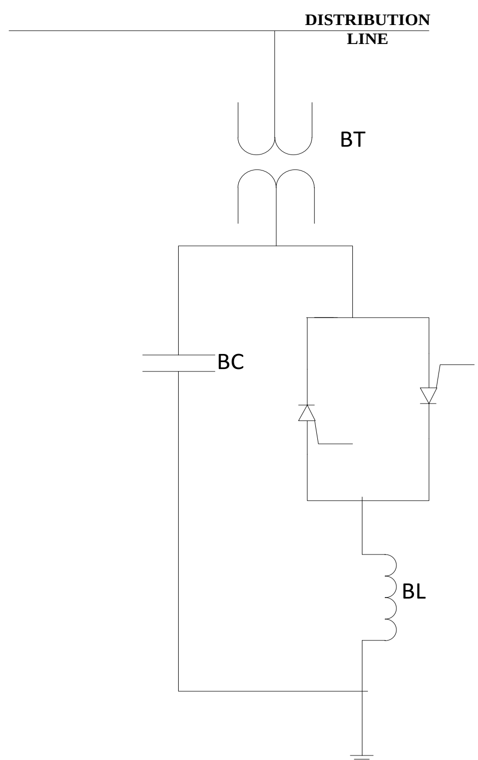
The fixed-capacitor banks which are usually connected in a star configuration are split into more than one 3-phase group. Each capacitor contains a small tuning inductor connected in series and tunes the branch to act as a filter for a specific harmonic order. For instance, one capacitor group is tuned to the 5thharmonic and another to the 7thharmonic, whereas another group is designed to act as a high-pass filter. At fundamental frequency, the tuning reactors slightly reduce the net MVA rating of the fixed capacitors [4]. The schematic diagram of a fixed capacitor thyristor controlled reactor is shown in figure 1.



The compensator susceptance B_{SVC} is given by (1)

$$B_{SVC} = \frac{B_T(B_c + B_{TCR})}{B_T + B_C + B_{TCR}} \quad (1)$$

Where B_T is the susceptance of the transformer and B_{TCR} is the variable from 0 to B_L according to the firing angle from 180° to 90°. The susceptance limits can be calculated in (1). Susceptance at the production (capacitive) limit, that is, with $B_{TCR}=0$ at $\alpha=180°$, is expressed in (2). Susceptance at the absorption (inductive) limit, that is, with $B_{TCR}=B_L$ at $\alpha=90°$ is given by (3).

$$B_{SVC\,\max} = \frac{B_T B_C}{B_T + B_C} \qquad (2)$$

$$B_{SVC\,\min} = \frac{B_T(B_C + B_L)}{B_T + B_C + B_L} \qquad (3)$$

By dimensioning the ratings of the TCR and the capacitor, respectively, the production and absorption ranges can be selected according to the system requirements. It must be remembered that B_L is a negative quantity. The total susceptance B_{SVC} of the static VAr compensator does not change linearly with B_{TCR}. However if $(BC/B\sigma) << 1$ and $(BL/B\sigma) << 1$, which is usually the case, the nonlinearity is relatively small. The V-I characteristic of SVC is shown in figure 2

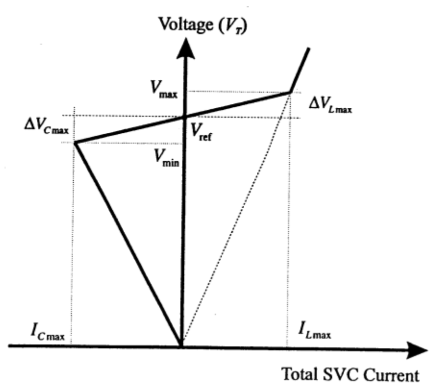


Figure 2

The voltage at which the static compensator neither absorbs nor generates reactive power is the reference voltage V_{ref} (figure 2). In practice, this reference voltage can be adjusted within the typical range of $\pm$10%. The slope of the characteristic represents a change in voltage with compensator current and therefore, can be considered as a slope reactance X_{SL}.

III. Fuzzy logic controller

A fuzzy logic controller is used where the system is non linear or ill processed or ill defined process. That can be easily controlled by a skilled human thinking without much knowledge of the dynamics of the system. Basic idea is to incorporate the expert experience of the human operator in the design of the controller in controlling a process whose input-output relationship is described by collection of fuzzy control rules(eg if-then rules) involving linguistic variables rather than a complicated dynamic model. A typical architecture of a fuzzy logic controller is shown in figure 3

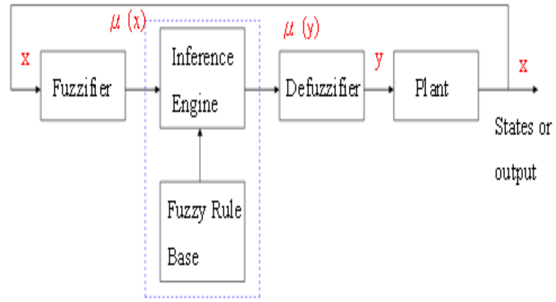
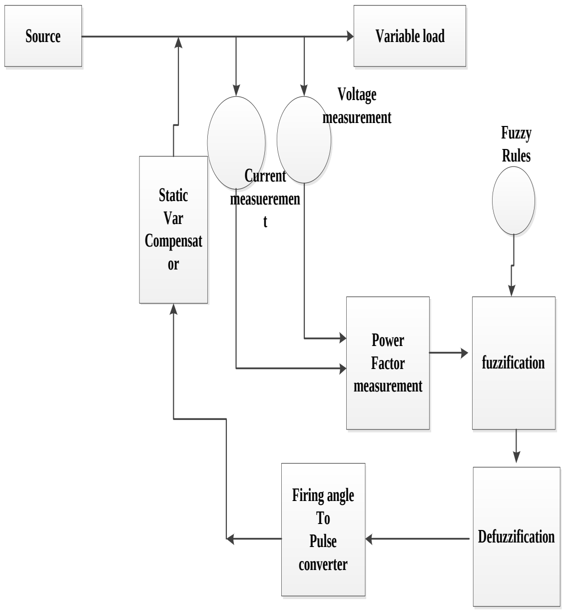


Figure 3

If the output from the defuzzifier is not a control action for a plant, then the system is fuzzy logic decision system. The fuzzifier has the effect of transforming crisp measured data (e.g. speed is 10 mph) into suitable linguistic values (i.e. fuzzy sets, for example, speed is too slow).~ The fuzzy rule base stores the empirical knowledge of the operation of the process of the domain experts.~ The inference engine is the kernel of a FLC, and it has the capability of simulating human decision making by performing approximate reasoning to achieve a desired control strategy.~ The defuzzifier is utilized to yield a non fuzzy decision or control action from an inferred fuzzy control action by the inference engine.

IV. Proposed methodology and structure

As seen the susceptance of the fixed capacitor type thyristor controlled reactor (FC-TCR) can be controlled by controlling the firing angle of the TCR branch. So this can be implemented to improve the power factor of the system. The power factor of the load goes down due to the increase of reactive power absorption or increase of the reactive power injection. In first case power factor goes down in the lagging mode and power factor goes down in leading mode in the later case. It is seen that susceptance is capacitive when the firing angle is near to 90° and susceptance is inductive when the power factor is near to 180°. On the basis of this knowledge a fuzzy control system is proposed which can be used to increase the load power factor. Implementation of the proposed system can be made by the suitable microprocessor programming. The algorithm that illustrates the proposed control system is shown by the block diagram of figure 4.



as seen from the block diagram voltage measurement and current measurement is being done then they are fed to a block which measures the power factor of the load. Let the measured voltage be $V\angle\theta_1$ and the measured current be $I\angle\theta_2$. Then the total power S will be given as

$$S=V*I\ \angle\theta_1-\theta_2 \quad (4)$$

Then

The real power absorbed by the load P is given by

$$P=V*I*\cos(\theta_1-\theta_2) \quad (5)$$

And

The reactive power absorbed by the load Q is given by

$$Q= P=V*I*\sin(\theta_1-\theta_2) \quad (6)$$

Value of Q is negative if θ_1 is less than θ_2 this means that instead of absorbing the reactive power load is delivering the reactive power. This occurs when the load is capacitive in nature. Now the power factor of the system will be given as

$$P.F=\frac{P}{S} \quad (7)$$

Where P is the real power absorbed by the load and Q is the reactive power absorbed by the load. The power factor angle φ is given as

$$\Phi=\tan^{-1}\frac{Q}{P} \quad (8)$$

The power factor angle φ id then fed to the fuzzifier which converts the firing angle input to the crisp output. On the basis of the knowledge of the relationship of the firing angle and power factor angle a fuzzy if then rule will be made to obtain the crisp firing angle output as the output of the fuzzifier. The defuzzifier then converts the crisp firing angle output to single value firing angle which will then be given to the firing angle to pulse converter which generates the firing pulse for the thristor in a TCR so change the susceptance dynamically.

V. Conclusions

Fixed capacitor type thyristor controlled reactor (FC-TCR) has the dynamic capability of variable susceptance which can be implemented to improve the load power factor. The fuzzy control block is been used due to which the mathematical relationship of the system is not needed just a little knowledge of the behavior of the system is needed. As the components are less and algorithm is simple the proposed methodology can economically be implemented in a single phase system to improve the load power factor**.**

VI. References

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